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SPEAKER SYSTEM AND A METHOD FOR IMPROVING SOUND QUALITY THEREOF

This application is a continuation of application Ser. No. 08/373,250, filed Feb. 7, 1995 now abandoned which is a 371 of PCT/JP92/01721 filed Dec. 28, 1992.

TECHNICAL FIELD

This invention relates to a cabinet where little standing waves are generated, particularly to a speaker system comprising a cabinet suitable for reproducing high fidelity sounds, and a method for improving sound quality thereof.

BACKGROUND ART

Hitherto, a closed type cabinet, a bass-reflex type cabinet and a non-back baffle type cabinet have been known as a speaker cabinet. In the conventional cabinets, standing waves are generated by resonance of air inside the cabinet. The standing waves cause various problems as follows:

(1) The standing waves interrupt movement faithful to signals of a diaphragm of a speaker unit. As a result, an output sound frequency characteristic is disturbed and reproduced sound is distorted.

(2) A wall surface of the cabinet resonates with standing waves to produce sounds of the cabinet. A reproduced sound accompanied by the sounds of cabinet is different from an original sound. Also, the reproduced sound sounds as if it winds round the cabinet and has little expansion.

(3) A resonant sound of the standing waves leaks through the diaphragm of the speaker unit or a wall of the cabinet. Consequently, a specific sound of the reproduced sound has reverberation and is not clear. For solving these problems, various proposals have been made.

For example, in regard to the above problem (1), there have been proposed a method for filling up the cabinet with a sound absorbing material; a method for using a perforated sound absorbing board (Japanese U.M. Publication [JITSUKOSHO] No. 49-27241); a method for using a perforated sound absorbing board together with a sound absorbing material (Japanese U. M. Publication [JITSUKAISHO] No. 54-3930); a method for setting a sound reflecting board (Japanese U. M. Publication [JITSUKOSHO] No. 57-49492); a method for using a honeycomb core together with a sound absorbing material (Japanese Patent Publication [TOKUKOSHO] No. 58-45236); and a method for providing a sound absorbing cabinet inside the cabinet (Japanese Patent Publication [TOKUKOSHO] No. 61-61597. For the problem (2), it has been proposed that walls of a cabinet are thickened. For the problem (3), a method for covering an opening of a frame of a speaker unit with a sound absorbing material has been known.

However, these proposals have the following disadvantages.

(1) In case the cabinet is filled with the sound absorbing material, a lively, dynamic sound can not be reproduced. With the perforated board, only a special standing wave having a wave length corresponding to a size of the perforation can be absorbed to thereby have little absorbing effect. Thus, a plurality of standing waves is generated in the cabinet, which results in no practical use. In case the perforated board is used together with the sound absorbing material, various problems accompanied by mal-effects of the sound absorbing material arise. In case the sound reflecting board is used to scatter a sound, it is necessary to select

a material, size, shape and setting direction of the sound reflecting board according to a direction and a wave length of the standing wave. Thus, it is difficult to cope with many standing waves. Further, in case an uneven diffusion reflecting structure comprising the sound reflecting board is formed on an inner surface of the cabinet, an effective volume of the cabinet decreases. The honeycomb type core has a large total opening area so that it has an effect only for a specific sound. When the honeycomb core is used together with a sound absorbing material, a reproduced sound is accompanied by a mal-effect of the sound absorbing material. It has been proposed that a sound absorbing cabinet is provided in the cabinet. However, the purpose is to raise a reproduced sound pressure level by resonating with a sound of specific frequency. The sound absorbing cabinet having small internal loss makes a reproduced sound an unnatural sound accompanied by a reverberation, in resonance with a sound having a specific frequency, if used in a wide range sound reproducing speaker system.

(2) In case the wall of the speaker cabinet is since the standing waves is not suppressed, the problem of the diaphragm of the speaker unit can not be solved.

(3) In case the opening of the frame of the speaker unit is covered with the sound absorbing material, a large quantity of the sound absorbing material causes a mal-effect to a tone quality. Also, it is difficult to eliminate mal-effects of the standing waves having frequencies less than 300 Hz with only the sound absorbing material.

Accordingly, the present invention is to provide a speaker system which can reproduce a clear bass sound and a stereophonic sound having an expanded sound field and a method for improving sound quality thereof.

DISCLOSURE OF THE INVENTION

An object of the present invention is accomplished by a speaker system wherein a cabinet has a space enclosed by partition walls therein, the partition walls are formed of a material having high internal loss and semi-transmission for a plurality of standing waves, a total capacity of the space is more than one tenth of a capacity of the cabinet, and a closed end of the space is positioned between one-half and four-fifths of a distance from a longitudinal end of the cabinet to the other. Also, a ratio of cross-sections of the space and the cabinet is preferably larger than one to five in the cross-section crossing the longitudinal direction of the cabinet. The space may be replaced by a plurality of spaces of different dimensions. Also, a total area of opening areas of the space surrounded by the partition walls is preferably less than one tenth of a total surface area of the partition walls. Further, the partition walls may have a density per area of more than 0.01 g/cm² to less than 1.0 g/cm² and have a density per volume of more than 0.1 g/cm³. The partition walls may be made of paper. The space may be enclosed by the partition walls and the acoustic isolation walls. The space also may be enclosed by the partition walls, the acoustic isolation walls and a reinforcing member for the acoustic isolation walls. The effect of the present invention is also fully exhibited by the speaker system having the space formed of a paper box.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a central cross section of a first embodiment of a cylindrical type speaker system according to the present invention.

FIG. 2 is a graph illustrating a characteristic of transmission energy to frequency of the first embodiment.

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FIG. 3(A) is a perspective view of a second embodiment according to the present invention and

FIG. 3(B) is a graph showing a frequency characteristic of the second embodiment.

FIG. 4(A) is a perspective view of a third embodiment suitable for a box type speaker system according to the present invention,

FIG. 4(B) is a perspective view of a paper box assembly, and

FIG. 4(C) is a graph showing a frequency characteristic of the third embodiment.

FIG. 5(A) is a perspective view of a fourth embodiment according to the present invention

FIG. 5(B) is a section view showing an example of a part of a speaker unit.

FIG. 6(A) is a perspective view of a fifth embodiment according to the present invention,

FIGS. 6(B) and 6(C) are perspective views of paper boxes, and

FIG. 6(D) is a graph showing a frequency characteristic of the fifth embodiment.

FIG. 7(A) is a perspective view of a sixth embodiment according to the present invention,

FIG. 7(B) is a graph showing a frequency characteristic of the sixth embodiment.

FIG. 8(A) is a perspective view of a seventh embodiment according to the present invention,

FIG. 8(B) is a perspective view of a square tube,

FIG. 8(C) is perspective view of a paper box, and

FIG. 8(D) is a graph showing a frequency characteristic of the seventh embodiment.

FIG. 9(A) is a perspective view of a of a eighth embodiment according to the present invention,

FIGS. 9(B) and 9(C) are perspective views of closed boxes, and

FIG. 9(D) is a sectional view for showing an assembly system of a part of cabinets.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Based on embodiments shown in the attached drawings, speaker systems of the present invention are described hereunder. However, the present invention is not limited to the embodiments.

FIG. 1 is a central cross section of the first embodiment of a cylindrical speaker cabinet according to the present invention.

The speaker system of a first embodiment is a tallboy type, non-directional sound radiation speaker system including a speaker cabinet (hereinafter called "cabinet") 1 formed into a longitudinal shape. The cabinet 1 comprises a front baffle 2 and a speaker unit 3 fitted upwardly, at a top of the cabinet. The cabinet 1 comprises side walls 4 formed of a big paper tube of 25 cm in inside diameter, — m in length, (L) and 5 cm in thickness, used as a building material. The side walls 4 are mourned on a thick board 5, and the front baffle 2 made of a plywood 1.1 cm in thickness is mounted on the paper tubes. A sound resonance suppressing apparatus type 1 corresponding to the cabinet 1 comprises a plurality of cylindrical tubes 6a, 6b, 6c i.e. partition wall P, to form spaces S therein. The cylindrical tubes are all closed at both ends, and are made of a double wall corrugated cardboard of 0.4 cm in thickness and 0.07 g/cm^2 in density per area. The

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cylindrical tube 6a is 23 cm in outside diameter and 88 cm in length l and has two cylindrical tubes 6b (18 cm in outside diameter, 12 cm in length, respectively), therein. The respective cylindrical tubes 6b have two cylindrical tubes 6c (12 cm in outside diameter, 19 cm in length) therein. Accordingly, four cylindrical tubes 6c are disposed in the cylindrical tube 6a in total. An axis of the big paper tube need not accord with axes of respective cylindrical tubes. A transmission energy frequency characteristic of the speaker system of the first embodiment is shown by a curved line in FIG. 2. A dotted line shows a frequency characteristic of the speaker system formed by eliminating the sound resonance suppressing apparatus type 1 from the first embodiment. The frequency characteristics were measured with a microphone disposed at a distance of 10 cm from an edge surface of the speaker unit 3 on the axis, by scanning in sine waves. It is apparent from the graph that a distortion of the frequency response is improved. Clearness of middle and bass sounds is increased, and a sound expansion increases.

Although not shown in the drawings, as a modification of embodiment 1 according to the present invention, two cylindrical tubes 6c located near the speaker unit 3 may be removed. Also, the cylindrical tube 6a may be excluded. Or three cylindrical tubes closed at both ends and having a diameter of 18 cm and a length of 30 cm may be provided instead of the cylindrical tubes 6a, 6b, 6c. Further, the same effect as described above can be obtained by a speaker system comprising nine stacked cylindrical tubes closed at one end and having a diameter of 18 cm and a length of 10 cm. However, with an only cylindrical tube closed at both ends and having a diameter of 18 cm, a length of 85 cm and no partitions therein, a distortion of the frequency response in the vicinity of 180 Hz is not greatly improved. Further, in case a plurality of circular boards of double wall corrugated cardboard, having a diameter of 25.2 cm, is fitted in a paper tube of an inside diameter of 25 cm so that the paper tube is divided into plural parts in a longitudinal direction, although listening feeling of sounds is improved, distortion is generated in another region in view of the frequency characteristic.

Incidentally, in case a sheet of kraft paper, Japanese paper, cloth, or resin with a small elasticity and a large internal loss, which becomes less than 0.3 mm in thickness when pressed at the time of attaching the speaker unit, is sandwiched between the speaker unit 3 and the front baffle 2, a music, such as jazz including many impact sounds, can be easily heard.

FIG. 3(A) is a perspective view of a second embodiment of a speaker system according to the present invention.

Side walls 8 of a cabinet 7 of the second embodiment are formed of paper tubes having an inside diameter of 25 cm, as in the first embodiment, but its height is 117 cm. The sound resonance suppressing apparatus 2 type 9 comprises a square tube i.e. partition wall P made of a double wall corrugated cardboard of 0.4 cm in thickness and paper tube legs having a diameter of 4 cm and a length of 4 cm. Both ends of the square tube are open to form opening areas O. More specifically, a corrugated cardboard square box with a bottom 9a i.e. closed end C having an outside width of 17 cm, a depth of 17 cm and a height of 57 cm is fixed at the bottom, by a adhesive tape, to a corrugated cardboard tube having an outside width of 17 cm, a depth of 17 cm and a height of 35 cm, and the legs are provided thereunder. Therefore, the bottom 9a functions as a partition wall in a vertical direction. A characteristic of transmission energy to frequency of the second embodiment is shown by a curved line in FIG. 3(B). A dotted line shows a characteristic in case

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that the sound resonance suppressing apparatus 2 type 9 is removed. It is apparent from the graph that the distortion of the frequency response caused by standing waves is reduced by the sound resonance suppressing apparatus 2 type 9 according to the present invention. Clearness of a bass sound region is improved without reducing dynamic sounds.

Conditions under which the same effect can be obtained by the mode of the present embodiment are described hereinbelow. Effect can be obtained by closing the square tube at one or both ends by a corrugated cardboard or a thick board. It is preferable that a cross sectional area of the square tube is about $50 \pm 30\%$ of a cross sectional area of the paper tube having a diameter of 25 cm, but in case a total area of cross sectional areas of tube each having a smaller diameter, is the same as the above described rate, a plurality of tubes having the smaller diameter may be used.

The partition wall 9a crossing the cabinet in a longitudinal direction is preferably disposed at a position of one-half to four-fifths of a distance from a sound source to an end portion of the cabinet, or at a position of one-half to four-fifths of a distance from one end of the cabinet to the other end.

The partition wall 9a may have a circular shape, a semicircular shape, or a doughnut shape to obtain good effect. The partition wall 9a may be disposed between the partition wall 9b and the side wall 8 in a longitudinal direction. Also, it is preferable that edge portions of the partition wall 9a contact 4(A) the partition wall 9b in the longitudinal direction.

It is preferable that the partition wall 9b in the longitudinal direction continues from an end of the partition wall 9a to an end of the cabinet. In case the partition wall 9b is semi-transmissive for standing waves in a long wavelength side generated in the cabinet 7, the partition wall 9a may have acoustic isolation.

Although not shown in the drawing, as a modified speaker system of the embodiment 2 according to the present invention, in case a reduced structure having a cross section of about one-half of that of the square tube 9 and a partition wall corresponding to the partition wall 9a provided between one-half to four-fifths of a distance from the front baffle 2 to the partition wall 9a, is additionally mounted inside the square tube 9 of a sound resonance suppressing apparatus 2 type, unevenness of the frequency characteristic is further reduced.

FIG. 4 is a perspective view of a third embodiment. This embodiment relates to improvement in tone quality by a cabinet in a shape of a rectangular parallelepiped.

A cabinet 10 is a closed-type cabinet made of a plywood or particle board of 2 cm in thickness, and having an inside height of 75 cm a width of 50 cm and a depth of 25 cm. A speaker unit (not shown) is a full range speaker having an aperture of 38 cm in diameter and attached to an opening 12 of a front baffle 11.

The same cabinet 10 and the speaker unit as those used in this embodiment are used in embodiments shown in FIGS. 5 through 8.

A sound resonance suppressing apparatus 3 type is formed of paper box assemblies 13. The paper box assembly 13 is formed of a set of five closed boxes integrated by an adhesive tape as shown in FIG. 4(B). Each of the closed boxes is made of a cardboard of 7 cm \times 7 cm \times 20 cm and having a thickness of 0.06 cm and a density per area of 0.04 g/cm². The respective paper box assemblies are brought close to a ceiling 14, back baffle 15 and both sides walls 16, 17 of the cabinet 10, and fixed by an adhesive tape.

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FIG. 4(C) shows a frequency characteristic of back sound in the cabinet.

The frequency characteristic was measured by scanning in sine waves with a microphone disposed in the vicinity of an opening of a speaker unit frame. A cord of the microphone was provided through an insertion opening (not shown) provided on the cabinet 10. A curved line shows the frequency response with the sound resonance suppressing apparatus 3 type, and a dotted line shows the frequency response without the sound resonance suppressing apparatus 3 type. It is apparent from the graph that distortion in the frequency characteristic is especially reduced in a region below 500 Hz. Sounds do not lose dynamic sense, and clearness of bass sounds is improved.

In the embodiment, two paper box assemblies were used, but four or six paper box assemblies may be used.

FIG. 5(A) is a perspective view of a fourth embodiment.

A sound resonance suppressing apparatus 4 type used in the fourth embodiment is formed of angle type corrugated cardboards 19a, 19b, 19c and 19d. The angle type corrugated cardboards are formed of a double wall corrugated cardboard of a thickness of 0.4 cm and a width of 25.2 cm so that the tops of the angle portions i.e. height from a bottom portion are 7 cm, 11 cm, 6 cm and 3 cm are the angle cardboard fitted in the peripheral portions of the cabinet between the front baffle 11 and the back baffle 15. For the angle corrugated cardboard 19a, four corrugated cardboards of 25.2 cm \times 24 cm were used; for the angle corrugated cardboard 19b, four corrugated cardboards of 25.2 cm \times 18 cm were used; for angle corrugated cardboard 19c, two corrugated cardboards of 25.2 cm \times 26 cm were used; and for angle corrugated cardboard 19d, two corrugated cardboards of 25.2 cm \times 25.3 cm were used. In the fourth embodiment, the approximately same effect as that of the third embodiment was obtained.

The effect of the invention is considered to be greater than the diffusion effect of bass sounds, by providing non-parallel surfaces with a double wall corrugated cardboard as a reflecting board.

Also, in case a speaker unit having a weight heavier than 1 kg is used in the fourth embodiment, if the speaker unit is suspended by a chain so that a frame abuts against a front baffle, a music, such as jazz, having impact sounds came is improved. In this case, the frame and the baffle may be fixed together by a bolt to prevent damages caused when the speaker system is moved. Or, the frame may be provided with boards for preventing the speaker unit from being slipped on front, back and side portions of peripheral edge thereof. FIG. 5(B) shows an example of the above structure.

A chain positioning member 22 (iron fitting) is used so that a speaker unit 21 suspended by a stainless steel chain 20 abuts against the front baffle 11. A turnbuckle 23 is used for positioning the speaker unit in a vertical direction. It is better to provide a suspension fitting 24 at a position where the front baffle and the side wall join.

FIG. 6(A) is a perspective view of a fifth embodiment.

A sound resonance suppressing apparatus 5 type is formed of paper boxes 25 and a paper box 26. The paper box 25 is a closed type box made of a cardboard of 0.06 cm in thickness which is waterproofed on a surface, and has a dimension of 7 cm \times 7 cm \times 20 cm, as shown in FIG. 6(B). The twenty-nine paper boxes are disposed along a ceiling board, a bottom board and side walls inside the cabinet, as shown in the drawing, and fixed by an adhesive tape or drawing pins, if necessary. The paper box 26 is a closed box (5 cm \times 34 cm \times 36 cm) made of a double wall corrugated

cardboard of 0.4 cm in thickness, as shown in FIG. 6(C), and is fixed on the back baffle 15 at a back side of the speaker unit.

FIG. 6(D) is a graph showing a frequency characteristic of sounds at the back side. It is apparent from the graph that the standing waves are reduced. Especially, in the fifth embodiment, reduction of the standing waves in the vicinity of 650 Hz is due to the paper box 26 shown in the drawing. Clearness of middle and bass sounds is improved. Although the twenty-nine paper boxes 25 were used in the embodiment, another fourteen paper boxes may be added to obtain good effect. The additional fourteen paper boxes are stacked on the bottom board so that forty three paper boxes in total are used. A bass sound region reproduction limit and reproduction levels in middle and bass sound regions are not greatly changed.

FIG. 7(A) is a perspective view of a sixth embodiment.

A sound resonance suppressing apparatus 6 type of the sixth embodiment is formed of a closed box 26 (5 cm×34 cm×36 cm) made of a double wall corrugated cardboard of 0.4 cm in thickness as used in the sound resonance suppressing apparatus 5 type of the fifth embodiment, and double wall corrugated cardboards 27 having a thickness of 0.4 cm and a width of 25.2 cm. The closed box 26 is fixed to a back baffle as in the apparatus 5 type, and the double wall corrugated cardboards 27 are fitted in parallel to a ceiling board, a bottom board and side boards between front and back baffles so that a plurality of closed spaces are formed therein.

In the sixth embodiment, $H=75$ cm, $H_1=H_3=28$ cm, $H_2=19$ cm, $H_4=6$ cm, $W=50$ cm, $W_1=W_2=7$ cm, and $D=25$ cm.

FIG. 7(B) is a graph showing frequency characteristics of the back side sounds in the sixth embodiment.

It is apparent from the graph that distortion in the frequency characteristic caused by standing waves is reduced. Clearness of middle and bass sounds is improved.

As a modification of the sixth embodiment, a sound resonance suppressing apparatus is considered, wherein a height H_1 need not be equal to H_3 and the width W_1 need not be equal to W_2 . Further, double wall corrugated cardboards 27a for determining lengths of W_1 , W_2 and contacting both side walls may be replaced with thick boards so that the thick boards can also be used as side wall reinforcing members. In the same way, the double wall corrugated cardboards contacting the front baffle, back baffle, ceiling board and bottom board may be partly replaced by thick boards and also used as reinforcing members therefor.

FIG. 8(A) is a perspective view of a seventh embodiment.

A sound resonance suppressing apparatus 7 type of the seventh embodiment is formed of ten square tubes 28 made of a cardboard and having two inner partitions between closed both ends as shown in FIG. 8(B), and two closed-type corrugated cardboard box 29 as shown in FIG. 8(C). Two sets of the five square tubes 28 are provided uprightly near both side walls, respectively. The two closed-type corrugated cardboard boxes are fixed side by side to the back baffle at a position opposite to the speaker unit. The square tube 28 is made of a cardboard of 0.06 cm in thickness, and composed of a closed box of 7 cm×7 cm×20 cm a box of 7 cm×7 cm×24 cm having an open top end which is disposed below the closed box and fixed by an adhesive tape, and another box of 7 cm×7 cm×24 cm having an open top end which is disposed below the box having an open top end and fixed by an adhesive tape to make a square tube of 7 cm×7

cm×68 cm. The two closed corrugated cardboard boxes are made of a double wall corrugated cardboard of 0.4 cm in thickness and have a dimension of 5 cm×15 cm×22 cm.

FIG. 8(D) is a graph showing frequency characteristics of sounds at the back side in the seventh embodiment. A dotted line shows a frequency characteristic when the sound resonance suppressing apparatus is not used, and a curved line shows a frequency characteristic when the sound resonance suppressing apparatus is used. It is apparent from the graph that standing waves are reduced in the embodiment. Distortion and reverberation are removed, clearness of middle and bass sounds is increased, and dynamic sounds are reproduced. Ears sense as if sounds come from all the surrounding areas rather than the speaker cabinet, and sounds having expansion can be reproduced. Incidentally, in case the cardboard or the corrugated cardboard constituting the sound resonance suppressing apparatus 7 type is crumpled to soften and used, tone quality can be further improved. In the method of the invention, in case the inside partitions of the square tubes are all removed, the effect in the region over 300 Hz is the same as that of the case where the sound resonance suppressing apparatus is used, while distortion in the region of 200 Hz is not greatly reduced.

FIG. 9(A) is a perspective view of an eighth embodiment. The embodiment relates to an improvement of tone quality in a large speaker cabinet.

A cabinet 30 is a closed-type speaker cabinet having a height of 160 cm, a width of 60 cm and a depth of 40 cm in an outside dimension, wherein three double wall corrugated cardboards 36b of 0.4 cm in thickness are attached to an inside of a plywood 36a of 1.4 cm in thickness, as shown in FIG. 9(D). The cabinet has a structure where three cabinets 31, 32, 33 are stacked so that the cabinet is cut off at heights of 70 cm and 120 cm from a bottom. The stacking portion, as shown in FIG. 9(D), includes a fitting portion 35 for positioning which is reinforced with a thick board 34 and a rotatable fixing member 37 for preventing the cabinets from being fallen down by engaging with the upper and lower cabinets. A speaker unit is a full range speaker having an aperture of 38 cm which is suspended by a chain so that the speaker unit (not shown) abuts against a front baffle of an intermediate cabinet 32.

The sound resonance suppressing apparatus 8 type is formed of closed boxes 38, 39, 40, 41, 42, 43, 44, 45 and 46 made of a double wall corrugated cardboard of 0.4 cm in thickness. The closed boxes 38, 39 and 40 have a depth of 7 cm, and as shown in FIG. 9(B), its representative example has internal partitions 47. The closed boxes 38, 39 and 40 are attached to the back baffles of the respective cabinets 31, 32 and 33, as shown in FIG. 9(A). Closed boxes 41, 42, 43, 44, 45 and 46 respectively have inner boxes 48 inside the outer boxes in a shape of a triangle pole, as shown in FIG. 9(C). The inner box 48 has a cross section of one half of that of the outer box, and is partitioned into three portions therein. The closed boxes 41, 42, 45 and 46 are attached to the front baffles of the respective cabinets 31 and 33. The closed boxes 43 and 44 are attached to the side walls of the cabinet 32.

Even in the large speaker system of, this embodiment, reproduced sounds having no distortion, no discomfort, high clearness and improved expansion can be obtained so that TV sounds do not disturb person's ears.

While the representative embodiments of the invention have been explained hereinabove, the present invention is not limited to these embodiments.

As a material for the partition walls to be used in the invention, in addition to a corrugated cardboard and a